Specifications - Field-emission transmission electron microscope

General Description

The required instrument is a 200 kV, field-emission, analytical transmission electron microscope for the purpose of materials analysis at atomic resolution. The instrument must operate in both fixed probe (TEM) and scanning probe (STEM) modes. The instrument must have an energy-dispersive x-ray spectrometer (EDS) and an energy loss spectroscopy (EELS) and filtering system, usable in both TEM and STEM modes. The instrument must have Lorentz imaging capability. Standard operating conditions of the instrument must include: bright field (BF) and dark field (DF) imaging in TEM and STEM modes; high-angle, annular, dark field (HAADF) imaging in STEM mode; selected area, convergent beam and nanoprobe electron diffraction modes. The operation of the EDS must be compatible with all imaging modes and allow for simultaneous collection of EELS data.

The field emission transmission electron microscope must meet or exceed the following minimum specifications:

I. General System Specifications

a. 200 kV maximum operating voltage, user selectable in 50 V increments from 80 kV to 200 kV inclusive.
b. Voltage stability of 1 ppm/min or better.
c. Field emission gun with a Schottky emitter.
d. There must an automated startup procedure for setting emitter conditions that the user initiates with a single button or single software selection ("mouse-click").
e. The emission current must be at least 0.5 nA for a focused probe of 1nm diameter (full width at half maximum).
f. The emission current must be stable to 1% in any 30 minute period.
g. The long-term stability of the emission current for periods of 2 to 24 hours must be < 1.5% per hour.
h. No flashing of the tip will be required to maintain stable emission current.
i. Dark field tilt must be provided with a minimum tilt range of ±5° in x and y.
j. Switching between bright field and dark field conditions should be achieved by a push button or mouse-click.
k. There shall be at least 4 condenser apertures.
l. The instrument must provide Lorentz imaging capability with a resolution of 2.5 nm or better.

II. Objective Lens Configuration

a. The spherical aberration coefficient of the lens must not exceed 0.5 mm.
b. The chromatic aberration coefficient of the lens must not exceed 1.0 mm.
c. The objective lens current stability should be 1ppm/min or greater at 200kV or lower.
d. A pole piece must be included that guarantees resolution in TEM mode of 0.19 nm (first zero at Scherzer defocus), with an information limit of 0.14 nm or better.
e. The guaranteed STEM resolution for the pole piece will be at least 0.136 nm when used in conjunction with a high angle annular dark field detector, so that adjacent (004) silicon planes, i.e., the "silicon dumbbell", can be resolved.
f. A fully automated through focus system must be provided.
g. A wobbler with variable frequency for focusing and stigmation must be supplied.
h. An objective aperture that can be inserted during EDS data collection without degradation of the spectrum, so that high contrast for viewing the area of interest is maintained, is preferred.

III. Specimen Stage

a. A side-entry, eucentric-tilt goniometer with 5-axis motorized computer control is required.

    i. The five axes are x, y, and z translation, and two orthogonal tilting directions.
    ii. The x and y translation range must be at least 2 mm in each direction.
    iii. The z axis translation range must be at least 0.75 mm.
    iv. A minimum tilt range ±24° in either of the orthogonal directions must be provided with the pole piece specified in section II, paragraph d. A tilt range in excess of this minimum is preferred.

b. The cumulative sample drift in all five axes, measured as the apparent sample translation in the x-y plane, must be < 0.5 nm/min, within five minutes after moving the sample.
c. It must be possible to electronically record stage positions and return to stored positions through a push button or mouse-click selection.

d. A double-tilt beryllium specimen holder, commonly referred to as a low background holder, must be provided.
e. A single tilt holder must be provided.

IV. Vacuum System

a. The working pressure in the specimen area must be 6×10^{-6} Pa or better, with partial pressures of hydrocarbons and water vapor not to exceed 4×10^{-8} Pa and 4×10^{-6} Pa respectively.
b. The pressure at the gun must be 3×10^{-8} Pa or better.
c. A gun isolation valve must be provided.
d. A mechanism for column and specimen chamber bakeout must be provided.
e. A separate stage heater must be provided.
f. The stage heater and chamber bakeout must operate on independent timers for unattended start up and shut down.
g. A liquid nitrogen cold trap must be provided at the specimen area to trap contaminants in the specimen area.
h. The cold trap must not interfere with the full performance of the microscope.
i. The cold trap must have a heater to boil off any excess liquid nitrogen from the cold trap dewar after use.
j. The cold trap must prevent the formation of ice during observation of samples down to liquid nitrogen temperatures. No hardware, other than the cold trap, shall be required to achieve ice-free imaging conditions.

V. STEM configuration

a. A system for scanning mode operation of the microscope, including BF, DF, Z-contrast imaging and EDS and EELS mapping must be provided.
b. Detectors for BF, DF and HAADF imaging must be provided
c. Scanning modes must include image scan, line scan, spot scan, and externally-controlled scan.
d. The STEM controller must provide scan rotation correction and tilt correction.

VI. Photographic system

a. A moveable beam stop must be included.

b. A camera with fully automatic and manual modes must be provided.
c. The camera must accommodate a film magazine with a

capacity of at least 50 cut 3/1/4x4" films in separate holders.

d. A minimum of 100 film holders, two light-tight film magazines for unexposed film, and two light-tight magazines for exposed film must be provided. The film holders and magazines must not interfere with the energy-filtering system. If energy-filtering system consists of a post-column filter, the film holders and magazines must be of non-magnetic material.
e. The system must allow automatic recording of text data, including negative number, microscope voltage, camera length or magnification and operator inputted text.
f. A desiccator for storing up to 4 film magazines must be provided.

VII. Energy Filtering System

a. An energy filtering system, either in-column, or post-column must be provided.
b. The energy filter must not interfere with all other operations of the microscope, including STEM BF, DF and HAADF modes.
c. The energy filter system must be able to filter selected area and convergent beam diffraction patterns, and bright field and dark field images in TEM mode.
d. All hardware and software for energy filtered imaging and STEM spectrum imaging must be provided. The software must provide drift-corrected mapping capability.
e. Energy filtered HAADF capability is preferred.

VIII. Energy Dispersive X-Ray Analysis System

a. A 30mm^2 Si(Li) crystal EDS detector with a light element window must be provided.
b. The resolution of this detector must be at least 143 eV at manganese and 65 eV at fluorine.
c. A liquid nitrogen dewar for cooling the EDS detector must be included.
d. A digital pulse processor must be included.
e. Software for integration of the EDS system with the microscope operating system must be provided.
f. Software and hardware control for drift correction during spot, line and map acquisitions must be provided
g. Analytical software including standard and standardless quantitative analysis, spectrum imaging capability, and x-ray mapping must be provided.

h. A PC-compatible computer with at least a 17" monitor to run the EDS software must be provided.
i. The EDS detector must have an automatic retraction or shuttering system to protect the crystal from overload from backscattered electrons.

IX. Computer Control

a. Computer control software and a PC-compatible computer with either Windows 2000 or Windows NT to run the software must be provided. This software must allow the user to switch between operating modes of the microscope with a single "mouse-click" . The software must permit full operation of all detectors for image acquisition and EDS and energy-filtering systems. The microscope vendor must provide integration of the microscope operating system with all software necessary for image acquisition, including spectrum images, and EDS and EELS acquisition and processing.
b. All five axes of the goniometer must be controlled through the software.
c. It must be possible to control the specimen tilt with optional crystallographic software to automatically align specific crystallographic directions.
d. At least one flat panel display (18" or greater), or two flat panel displays (17" or larger) must be provided to display the microscope conditions and digitally acquired images.
e. The operating software must have at least four graduated levels of user access, including novice, advanced, systems administrator, and service, so that critical functions, such gun settings and alignments of the microscope, are not available to novice users.
f. Access to the microscope control software must be password protected, with separate passwords for each user, under control of the systems administrator.
g. A complete remote operation system for the microscope, including all computer controlled apertures, so that both service calls and routine operation can be performed over an appropriate network connection is preferred.

X. Water chiller

a. A water chiller must be provided. The water chiller should be

water-cooled, and connectable to a closed-loop, chilled water line provided by NRL. If the microscope requires compressed air to support any mechanical systems, such as pneumatic suspension or vacuums systems, an air compressor must be provided. It is expected that the successful offeror will visit NRL prior to the installation of the system to survey the installation site.

XI. Installation, Training and Documentation

a. The price of the system must include installation and pre-installation site inspections at NRL by the contractor.
b. Installation must be performed within 30 days of receipt of the equipment at NRL.
c. Installation of the microscope must include all software and hardware components necessary to operate the microscope including EDS and energy-filtering systems.
d. Installation must include connection to all electrical, water and gas plumbing services.
e. The contractor shall demonstrate that the system is in compliance with any of the specifications contained herein, as deemed appropriate by the NRL representative.
f. At the completion of the installation and demonstration of guaranteed specifications, the contractor shall provide on-location training at NRL for 5 people for a minimum of two days to familiarize the operators with proper operation and care of the instrument. In addition, the price must include tuition and supplies for one person to attend a one-week operator training class.
f. A full set of all written documentation customarily provided to the public with a commercial item shall be provided. This shall include users manual(s) or equivalent as well as copies of any software, and any manuals for the software included with the system, if customarily provided. This documentation must be received at NRL with the system hardware, unless other arrangements are agreed to by the NRL representative.

XII. Moving and Reinstallation

a. The contractor shall dismantle, pack and transport the microscope and all accessories to another location on the NRL DC site, pending the construction of a special-purpose nanoscience facility.
b. The date of the move is to be determined by NRL, within two years following the original installation date.

c. The contractor shall re-install the microscope and all accessories at the new NRL site. Once re-installed, the contractor must restore the system to initial performance specifications and repeat the acceptance demonstration.

XIII. Warranty and Service

Warranty Conditions: The contractor shall offer the Government at least the same warranty terms, including offers of extended warranties, offered to the general public in customary commercial practice. These warranty terms must be included in the system price. The period of the warranty shall begin upon acceptance. The warranty must include two preventative maintenance service calls and emergency service on an unlimited-as-need basis. Service response time for emergency service calls must be no greater than 24 hours.

XIII. Acceptance Testing

a. Acceptance testing of the instrument will be performed in two stages, first at the factory, (in the presence of the NRL representative), and finally at the NRL installation site. Acceptance testing will include all items in the minimum specifications, and any additional specifications that the contractor proposed. Acceptance will be conferred after the contractor has demonstrated compliance with all specifications, and all functions of the microscope have been fully operational without the need of a service visit for a period of 3 weeks.

SPECIFICATIONS FOR OPTION ITEMS

CLIN 0002 Plasma cleaner

A. A plasma cleaner for the simultaneous cleaning of sample and sample stage. The plasma cleaner must be usable as a plasma etcher. The entire plasma cleaning chamber must be accessed through a hinged lid, or other port.

CLIN 0003 Uninterruptible power supply

A. An uninterruptible power supply must be provided which is capable of supporting the microscope, including the full vacuum system, the energy filter, the EDS system and

associated computers, for a minimum of 12 minutes.

B. The operation of the UPS should be sufficient to maintain full microscope performance at the guaranteed TEM and STEM resolution stated in section II, paragraphs (d) and (e), for a minimum of 12 minutes.

CLIN 0004 Goniometer cover

A. An airtight goniometer cover must be provided to isolate the specimen stage from room air currents.

CLIN 0005 Double tilt cold stage.

A. A double tilt liquid nitrogen cooled stage must be provided.
B. A temperature controller for the cold stage must be included.

CLIN 0006 Double tilt rotation stage

A. A beryllium specimen stage with 360° rotation and ±25° tilt in two perpendicular directions is required.
B. The tilt and rotation must be separably adjustable at any orientation of the specimen cradle.